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The Return of the Machinery Question: Is it different this time?

Kaleb Luse

Abstract. Recent advances in artificial intelligence have the potential to seriously affect labor markets. Some believe that artificial intelligence will be the end of work for humans. Others believe that artificial intelligence is like any other technological innovation from the past and will create just as many jobs as it destroys. I conclude that while artificial intelligence can bring about many of the benefits of technological change seen in history, it drastically differs from innovations in the past and will result in massive unemployment. To ensure that everyone benefits from this huge step forward, policies need to be developed to accommodate the changes that will begin to take place in the labor markets. Along with presenting the different arguments and my conclusion, I also discuss some of these policies that can mitigate some of the impacts that artificial intelligence will have on labor markets.

> *For the first time since his creation man will be faced with his real, his permanent problem – how to use his freedom from pressing economic cares, how to occupy the leisure time which science and compound interest will have won for him, to live wisely and agreeably and well.*
>
> - John M. Keynes

I. Introduction

In 2013, the McKinsey Global Institute estimated that by 2025 artificial intelligence has the potential to replace over 140 million full-time workers, with an economic impact of approximately 6 trillion dollars annually (MGI 2013). This statistic and many others have once again raised what is commonly referred to as the machinery question. David Ricardo first posed the machinery question in 1821. The machinery question is "The opinion entertained by the laboring class, that the employment of machinery is frequently detrimental to their interests" (Ricardo 1821). Since its introduction, this view has proven to be false as job creation has continued to outpace technological change. If this is the case, then why is there again a debate about whether technological change will be beneficial or detrimental to the laboring class? Will history repeat itself or are we about to experience, as Keynes put it, "The greatest change which has ever occurred…for human beings" (Keynes 1933, 7)? One thing is certain; the change we are experiencing today is different from what we experienced in the past, and as I will argue, this change will cause massive unemployment and will affect everyone regardless of the industry they are in.

II. Lessons from History

To better understand the implications of artificial intelligence today, it helps to understand how technological change has affected labor markets in the past and how the laboring class responded to the changes.

One of the first recorded instances of technological change that threatened the jobs of the laboring class occurred in Britain with the invention of the stocking frame knitting machine by William Lee in 1589. To obtain a patent, Mr. Lee presented his machine to Queen Elizabeth whose response was "Thou aimest high, Master Lee. Consider thou what the invention could do to my poor subjects. It would assuredly bring them to ruin by depriving them of employment, thus making them beggars" (cited in Acemoglu and Robinson 2012, 182). Mr. Lee was denied a patent and the opposition to Mr. Lee's invention was so strong that he eventually had to leave Britain. After moving to France, Mr. Lee was able to obtain a patent from Henry IV. Mr. Lee opened a successful stocking manufacturing company in France, but his success was short lived as Henry IV was assassinated and after his assassination the political environment changed. Mr. Lee died soon after the assassination and his brother took the knitting machine back to England where it took another century before it was fully adopted.

William Lee's invention would be the beginning of many more changes that would occur in Britain. These changes, however, wouldn't occur until much later, in the 1800's. Though this was a period of accelerated change, this period also saw the rise of the Luddite movement. The Luddite movement, which lasted from 1811 to 1816, was a group of textile workers who feared that the introduction of new technology would render their skills obsolete. The Luddites took to burning mills and destroying machinery that took their jobs. Parliament took swift action and declared the act of burning mills or destroying machines punishable by death and used military action to put down the rebellion (Bailey 1998). Though many initially lost their jobs, the number of weavers employed between 1830 and 1900 quadrupled because of the increase in demand created by the cheaper prices (Economist 2016).

The second and third industrial revolutions saw less resistance than during the first industrial revolution. The primary reason there was less resistance was because it became clearer that while technology created winners and losers in the short run, in the long run technological change benefitted everyone in the form of higher wages, lower prices, and more jobs. This idea is articulated best by Arthur Hadley who says, "Machinery has not displaced labor. On the contrary, there has been a most conspicuous increase of employment in those lines where improvements in machinery have been the greatest" (Hadley 1901, 337). Though there was less resistance, people's fear of being replaced by machines were still present and this fear sparked President Lyndon B. Johnson to create the Blue-Ribbon National Commission on Technology, Automation, and Economic Progress. This commission was responsible for determining if the rise in productivity experienced at the time would outpace the demand for labor and thus create joblessness. The findings of the committee were consistent with that of the past, stating "Technological change (along with other forms of economic change) is an important determinant of the precise places, industries, and people affected by unemployment. But the general level of demand for goods and services is by far the most important factor determining how many are affected, how long they stay unemployed, and how hard it is for new entrants to the labor market to find jobs. The basic fact is that technology eliminates jobs, not work" (Bowen 1966).

III. What is Artificial Intelligence?

Artificial intelligence is man's attempt to create something as intelligent as himself or, more formally defined, giving computers the ability to perform actions that when performed by a human would be considered intelligent. Artificial intelligence has for years promised society technology that would revolutionize the way we do things but has under delivered on this promise. Until about 2010, researchers continued to publish papers on the advancement of artificial intelligence, but few, if any, useful applications were delivered.

Ironically, these unfulfilled promises, which were once the cause of great frustration, are now the cause of people's fears as artificial intelligence catches up to human intuition and starts delivering on promises made decades ago. The first and perhaps most widely known artificial intelligence application was IBM's Deep Blue, which beat the world chess champion, Garry Kasporov, in 1997. Though a huge achievement in artificial intelligence, Deep Blue was based on a rudimentary algorithm and it would be another 10 years before another such advancement would be made.

This next advancement was in another popular game, checkers. Rather than beating the best, Dr. Jonathan Schaeffer developed a proof that took nearly 20 years to complete with over 50 computers running non-stop performing calculations that showed if both players act perfectly the game will end in a draw. This proof "solved" the game of checkers, which is a much harder task then simply beating the world champion.

These advancements, however, did not serve many useful purposes other than showcasing that machines were catching up to humans in intelligence, a statement often contested. The statement is often contested as the first algorithm used to play chess relied on comparing millions of moves and selecting the best one, which differs from how humans think. The second algorithm took 20 years to prove with multiple computers looking at all possible moves in checkers, which people often argue does not show intelligence but just demonstrates how fast computers have become.

The recent successes of artificial intelligence in game playing has raised fears. Though being able to play a game may seem trivial, games create a near perfect environment for artificial intelligence as they have formal rules that are easy to define for a computer; they provide an environment where solving the game through exhaustive techniques such as generating all combinations of moves often proves impossible; and they demonstrate the applications' ability to learn. The algorithms used to play and learn the games can be modified to serve a wide variety of real problems. Because these algorithms can be adapted to solve real problems, advancements in these game-playing algorithms translate into steps forward in artificial intelligence's ability to replace work.

The first of these recent advances in artificial intelligence would come in 2011 when IBM's Watson defeated the Jeopardy! champions Brad Rutter and Ken Jennings. The algorithm used to beat Jeopardy! showcased a more intelligent application and has since shown to be very useful in business applications. In fact, since defeating Rutter and Jennings, IBM has been applying Watson to several business problems, and now offers several services using Watson as the engine (Ferrucci 2012). As the algorithms that make up Watson get more intelligent, as hardware gets cheaper, and as access to the internet becomes more available, reliable, and faster, the applications of Watson will continue to grow.

Perhaps the most surprising development in game-playing artificial intelligence was when DeepMind's AlphaGo beat the world champion in Go, Lee Sedol, a feat accomplished 10 years ahead of schedule (Hoffman 2016). Go is a popular game played in Asia and is far more complex than chess. Because of this, AlphaGo had to take advantage of algorithms that are far more complex than those used to beat the chess champion. Instead of being designed and formally defined by programmers, these algorithms learn in a similar manner as humans, further compounding the effect artificial intelligence could have on labor markets.

The most recent advancement of artificial intelligence in game playing has come out of Carnegie Mellon, where a professor and his grad student have just beaten the world's top Texas Hold'em players. Their application, named Libratus, is just another step forward for artificial intelligence as their approach is different than previous approaches. DeepMind's AlphaGo used a similar approach as Libratus called reinforcement learning, where the machine uses trial-and-error to learn good moves from bad moves. The difference between Libratus and AlphaGo is that AlphaGo learned by analyzing humans, whereas Libratus learned by playing against itself millions of times, essentially learning from scratch. The implications of applications like Libratus are vast because it means that if a defined set of rules can be made, then programmers can create a system that can outperform humans (Revell 2017).

The method that many of these game-playing applications use to surpass humans is what is really driving artificial intelligence. The method driving these changes is referred to as a neural network. There are several different kinds of neural networks. At their most basic level, these neural networks attempt to simulate how the brain works. While computers are still not able to completely model the activity of the brain, neural networks are making it a possibility in the future. For example, researchers have been able to mimic one second of 1% of the brains activity using the world's fourth largest supercomputer, though the entire computation took the computer 40 minutes (Whitman, 2013). The feat was done using a variation of a neural network and the entire project was done to show that one day it may be possible to mimic the brain.

The beginning of the explosion in more practical applications of artificial intelligence came with the announcement in 2009 that Google would be developing a self-driving car, a task thought impossible. What was once thought simply a publicity stunt is now a reality as Google took a huge step in 2015 by showing off the world's first fully self-driving ride on a public road. Though Google was the first to announce and develop a self-driving car, many other companies have followed suit. Uber announced in 2016 that it would be deploying a fleet of self-driving cars in Pittsburgh, already taking advantage of the business opportunities that lie ahead for self-driving cars. Though the cars are self-driving, regulations require a driver to be present. As technology becomes more advanced and as regulations catch up, billion dollar industries like transportation and logistics will benefit greatly from such technologies.

Artificial intelligence has accomplished a lot in the past decade and will continue to make huge strides as programmers and researchers are able to collect more data, develop smarter algorithms, and better understand how the human brain works. Though artificial intelligence has seen great strides, it is still unclear whether this technology will result in the end of work as described by Keynes and other philosophers or whether this technology will follow trends of the past and not displace workers in the long run.

IV. How Will Artificial Intelligence Affect Labor Markets?

The past suggests there is nothing to fear because artificial intelligence should destroy jobs but also new jobs in even higher quantities in other areas. This may not be the case, however, because of fundamental differences between artificial intelligence and the technological advancements of the past. In the past, technological change has often replaced many of the routine physical tasks held by blue collar workers but complemented the work of white collar workers (Griliches 1969). Artificial intelligence, however, has the capability of replacing not just routine cognitive tasks but abstract tasks too, even tasks that are considered unique to humans such as language processing (MGI 2017). Another difference between artificial intelligence and innovations of the past is the pace at which change is happening. The first industrial revolution lasted nearly two centuries and saw a slow shift from manual labor to automated labor as factories had to be built and equipment transported. The current revolution, often referred to as the fourth industrial revolution, appears to be happening ten times faster as it is much easier to distribute software than it is to build factories (MGI 2013). The question researchers continue to debate is how or if these differences will affect labor markets.

There are many researchers who argue that the introduction of artificial intelligence will have the same effect as technological change has had in the past and simply increase demand for products, thereby increasing employment (Albus 1983, Bessen 2016, Knapp 2017). For example, in the 1990's, discovery, the act of sorting through corporate documents to find ones relevant to the legal case at hand, became almost completely automated as the computers did a quicker and better job than humans and drastically reduced costs. One might have expected employment of paralegals to go down because a large part of their job involved sifting through hundreds of documents during discovery to find the relevant files. But according to the Bureau of Labor Statistics, the number of paralegals grew by 50,000 since 2000, which outpaced the regular growth rate of employment (Bureau of Labor Statistics n.d.). Because it is now easier and cheaper to find evidence, judges are more likely to allow new evidence thereby increasing the demand for discovery. Similarly, as the price of discovery falls, so too would the cost of hiring a lawyer, increasing the demand for lawyers and paralegals as well.

The introduction of ATM's is another tale of how computerizing the tasks of a job did not create unemployment. While ATM's were expected to take bank tellers' jobs, the number of bank tellers has instead grown at a steady rate despite the rapid growth of ATM's (Bessen 2016). This is a trend in many other occupations as well, where the introduction of computerization has helped that occupation grow faster than an occupation that has not adopted computers. Bessen (2016) empirically shows this by looking at the growth of occupations between 1980 and 2013. In his paper, he uses computer use data from the Current Population Surveys to determine which occupations have adopted computers versus those occupation that have not, using this as a proxy for the "degree of automation" in a given occupation. He also finds that while some occupations are negatively affected by computerization, on average employment grows faster in occupations that have higher computer use. More specifically, the paper shows that computer use is associated with growth in higher-paying occupations but declines in growth for lower-paying occupations.

Bessen's (2016) paper illustrates a key argument that is best said by David Autor, "Tasks that cannot be substituted by automation are generally complemented by it" (Autor 2015). Autor's statement, while succinctly said, is not a new idea. The idea is called the capital-skill complementarity hypothesis. This hypothesis states that as capital per worker increases, the number of hours demanded of the more-skilled workers increases proportionally faster than the hours of the less-skilled workers (Griliches 1969). Applied today, the introduction of computers that can do routine tasks and makes them cheaper tends to complement more abstract tasks and services. For example, managers spend nearly half of their time working on administrative tasks such as scheduling, hiring, and creating reports, which are all tasks that artificial intelligence can replace or augment (Kolbjornsrud, Amico and Thomas 2016). Replacing these tasks does not replace the manager but rather frees up her time to focus on creating strategy, developing employees, and solving problems, all of which make the manager more productive.

Though there are many who argue automation will continue as it has in the past, creating jobs, increasing demand, and overall benefitting most people, there are those who argue that artificial intelligence is different from technologies of the past. These people argue that artificial intelligence will result in different changes with different consequences and benefits.

A study done by Frey and Osborne (2013) has received a lot of attention lately due to its shocking results. Ironically, Frey and Osborne (2013) use a variation of statistical methods and neural networks to categorize the 702 occupations they looked at based on their susceptibility to computerization. The results of their study reveal that 47% of total US employment is at risk of being computerized using today's technologies. As technology continues to improve, there are those who fear that the only jobs left will be those that are "automation-proof" such as nursing, teaching, psychiatry, and counseling and that we cannot build an entire economy on these jobs alone (Nilsson 1984).

Though most research focuses on the future impact of artificial intelligence and computerization, some researchers believe that we are already experiencing the effects of computerization. The slow recovery of job growth, despite a rapid recovery of investment, has been attributed to computerization (Brynjolfsson and McAfee 2012). Many researchers have noted shifts in employment from middle-income manufacturing occupations to low-income occupations and attributed these shifts to computerization as well (Dorn and Autor 2013). Charles et. al (2013) and Jaimovich and Siu (2012) study the current decline in manufacturing employment and other routine jobs and attribute this to computerization, because computers have replaced many of the core tasks of manufacturing.

V. Analysis of Arguments

I don't believe mankind will ever be faced with its permanent problem of searching for something to do outside of work as suggested by Keynes but I also don't buy into a future where everyone is gainfully employed without some restructuring of the way our economy currently works.

Some argue that while computers may take over many jobs there are still jobs that can't be replaced by computers or machines. It is dangerous, however, to use this kind of thinking as many tasks once thought impossible are now a reality. For example, Levy and Murnane (2005) use this argument in their book and give driving as an example of a task that would be impossible to automate. Just four years after the release of their book, Google announced that it would be attempting to tackle this impossible task and within 5 years made this impossible task a reality. Levy and Murnane (2005) also give communication as an example of something that is unique to humans, but this task too has been seen significant advances. Natural language processing applications like Siri can recognize speech and translation applications like GeoFluent can translate speech in real-time. Perhaps the most significant breakthrough in natural language processing was when a super-computer named Eugene beat the Turing Test in 2014. The Turing Test has been around since the 1950's and has been used as the benchmark for truly intelligent applications. To pass the Turing Test, a computer is placed in one room, a human is placed in another and then judges sit in another separate room. The judges communicate with the computer and human through a computer screen. If after 5 minutes the computer has convinced 30% of the judges it is human than it passes the Turing Test. Though it seems like a rather simple test, it is a rather complex task for a computer as the nuances of language are vast and complicated. Passing the Turing Test for the first time since its creation in 1950 marks a significant advancement in both natural language processing and the field of artificial intelligence.

As mentioned earlier, some argue that there are some tasks for which people would prefer a human as opposed to a computer such as hospice care and servers. Though this may be the case with current technology, I would argue as computers become smarter and approach more human-like capabilities, people will prefer interacting with the computer as the computer will be cheaper, more efficient, and will be less prone to mistakes. In fact, there are examples today where people have chosen to interact with a computer instead of a human. For example, Walmart has created self-service lanes where some people prefer to check themselves out rather than go through the regular lanes where there is human-to-human interaction. A company named Ziosk creates an app that can be downloaded on a tablet and replaces restaurant servers because customers can purchase appetizers, drinks, and more from their table. This is another example where people have chosen the human-to-computer interaction in favor of human-to-human interaction because it's cheaper or more convenient. As these computers become more human in their interaction because of artificial intelligence, people will in larger numbers prefer these interactions over human ones.

Another common argument, given in the previous section, is that historically, the introduction of technology has only increased demand, creating more jobs. However, as technology takes over more tasks unique to humans, these jobs created by the increased demand caused by technology can also be taken by technology. For example, as self-driving cars become more widely adopted, they could transform the logistics industry and drive down transportation costs by almost completely eliminating the labor costs involved. This reduction in the cost of transporting goods would increase the demand for ground transportation of goods and would lead to an increase in the demand for someone with the ability to schedule the routing of these goods and the payment of the goods. These tasks, however, are also automatable. While the increase in demand may increase jobs whose tasks are not yet automatable, as artificial intelligence automates more tasks, more of these jobs created by the increase in demand will be able to be taken by computers. Historically, we have seen increases in employment with the introduction of new technologies, but as I argue above, a greater share of the jobs created will be able to be taken by artificial intelligence.

As mentioned above, Frey and Osburne (2013) have shown that with today's technology, 47% of the jobs in the United States are susceptible to computerization. I argue that number will continue to grow as technology continues to advance. The results of the study however raise the question "If so many tasks can be automated, why haven't they yet? The main reason these tasks have not yet been automated is because there has not been a good business reason to do so as the cost to do so exceeds the benefits. An example of this is at McDonalds. Self-service kiosks have been around for a while but McDonalds has only recently begun to test these because it has been cheaper to pay for the labor than to invest in the expensive capital required for these kiosks. Another example of this is pharmacy techs. Robots could easily take orders and fill prescriptions and replace many pharmacy jobs but since many pharmacies are generally small and only have 5 or so employees it is often too costly to invest in the equipment necessary to replace such jobs. However, as computers become cheaper and faster it will become feasible to automate more of these tasks. According to Moore's law, computers will get faster and will become cheaper. Moore's law states that the number of transistors that can fit onto a single microchip double's approximately every two years (Moore's Law 2010).

Moore's law doesn't just mean that it is more feasible to automate tasks; it also means that computers can make smarter decisions as many artificial intelligence algorithms are limited only be how many computations can be made in a second. Smarter applications mean that in areas where computers are approaching human intelligence, computers will soon surpass us, and areas where we have already been surpassed, computers will only get smarter. Moore's law may also help humans approach or perhaps pass the line known as technological singularity. Technological singularity is the point at which the invention of a super intelligent machine is able to surpass human knowledge and result in a runaway technological growth. Many researchers, however, do not believe that we will approach singularity for a while (Markoff 2016). Even if we never reach singularity, Moore's law could result in artificial *general* intelligence, which is the idea that the application has broad knowledge, much like humans, as opposed to knowledge of specific tasks. This would further affect labor markets and would surely result in the end of most human labor as a general intelligence machine would be able to do the same tasks a human could but for a lot less.

Moore's law, however, only predicts increases in the power of the hardware used to run these applications. The true challenge in developing artificial general intelligence will be developing the software. Even so, as best stated by McAfee and Brynjolfsson (2012), the true consequences of Moore's law take place as humanity enters what is known as the second half of the chessboard. The analogy comes from an ancient story where the inventor of chess presents his game to the emperor who is so delighted by the game he allows the inventor to name his reward. The clever inventor asks for one grain of rice on the first square, two on the second, four on the third, and each successive square would be twice as much as the square before it. The emperor agrees but soon realizes the error of his judgement as the pile of rice by the end would be larger than Mount Everest because of the exponential growth that is occurring. The second half of the chessboard analogy refers to the fact that up until the second half of the chessboard the rice appears to be growing at a linear rate and at this point the emperor is still able to maintain his kingdom and the inventor is able to get away with a decent amount of rice. However, it is not until the second half that the exponential growth of the rice really begins and the same is true with computers. In 2013 we entered the second half of the chessboard for computing. Now that we have reached the second half of the chessboard, technology will grow at a pace much faster than before. For example, using Moore's law and the feat of simulating the brain given earlier in this paper, in just 40 years it will be possible to fully simulate the entire brain in real-time.

As shown in several other papers, the middle class is hollowing out (Brynjolfsson and McAfee 2012, Davidson 2014) and while there are some who believe this trend is temporary and that jobs will recover (Autor 2015), I argue that this trend will continue and be worse than what is portrayed in the previous papers. The primary argument given for a halt in this trend is that we will create jobs that can't be taken over by artificial intelligence. But as I show above, the increasing power of computers and artificial intelligence leaves very few jobs that can't be replaced by a computer. Middle class jobs will continue to hollow out as these are typically the most economically feasible to replace. However, as developers are better able to create computers that are more human-like, these computers will find themselves taking lower-skilled service occupations. The same is true of high-skilled occupations; as computers become more powerful and we are better able to understand and breakdown the tasks of these occupations, they too will be susceptible to artificial intelligence. The implications of such a change in the labor force require a drastic change in policy as well which I outline in the next section.

VI. Policy Implications

The policies I look at are aimed at what a single country can do to ensure the welfare of its citizens in the new economy. Though artificial intelligence has the potential to improve the lives of everyone on the planet, the policies required to do so would be far more complex than those aimed at a single country. Policies aimed at a global level are also less likely to be adopted as many of the wealthier nations are likely to lose if global policies are put in place, which is why I focus on policies a single country can take.

A. CONTINUOUS LEARNING

Most research states that the only way for laborers to stay relevant in this new economy is to emphasize education and to continue learning (Brynjolfsson and McAfee 2012). Though I disagree with these researchers on the degree to which this new economy will employ people, I do agree that more education and continuous learning will be important in the new economy. For those employed, continuous learning will be important as the skills required for the few jobs that still exist will likely be vast and changing. Though preventing an uneducated populous is reason enough to place importance on education, it will remain important as it will provide people the basic skills they will need to interact with many of the changes that are likely to occur and will also give people a sense of purpose.

B. UNIVERSAL BASIC INCOME

As more and more people become unable to work, not due to lack of skills or desire to work, but because there are simply not enough jobs and as the owners of capital continue to reap the huge rewards brought to them through artificial intelligence, it will be necessary to redistribute this wealth. One way that this could be done is in the form of a universal basic income. The benefits of a universal basic income would ensure that people without work would still be able to purchase the goods and services provided by the capitalists. It would also ensure that everyone in the U.S. would be able to benefit from the gains provided by artificial intelligence. Of course, one of the arguments against a universal basic income is that it could potentially discourage people from working, but in this new economy where many people are unable to work, the common economical argument against a universal basic income is negligible.

C. DECREASE WORK HOURS/RETIREMENT AGE

If we wanted to ensure that everyone was still able to work, one way to do so would be to decrease the number of hours one works or decrease the retirement age so that everyone could still be employed. This would still require some sort of wealth redistribution like the universal basic income mentioned above because working 20 hours a week until you were forty would not be sufficient to provide a living or a retirement. Though this could potentially solve the issue of not having enough work for everyone, some may be unable to obtain the skills necessary to participate in the kind of work that is left and would lose in the new economy. This would not be that drastic of a shift from what we experience today where people who are unable to obtain the skills necessary to compete in high-skilled, highly-paid work are left to take low-skilled, low-paid work. The same principle would hold in the new economy but instead of taking the low-skilled work, these workers would instead be left unemployed and rely on the redistribution of wealth.

VII. Conclusion

Despite the record of the past, artificial intelligence will result in permanent changes to labor markets because it is different this time. The speed at which change is happening and the endless tasks that can be replaced by artificial intelligence are the reason it is different this time. The increasing ability of artificial intelligence to automate tasks will result in massive unemployment and leave many losers in the new economy. Therefore, I suggest that policies will have to focus on redistributing wealth. Since many of the objections to redistribution lie in the disincentive to work, this system would be appropriate in the new economy. If we can successfully adopt such policies we can ensure that everyone gains from the advancements in artificial intelligence.

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